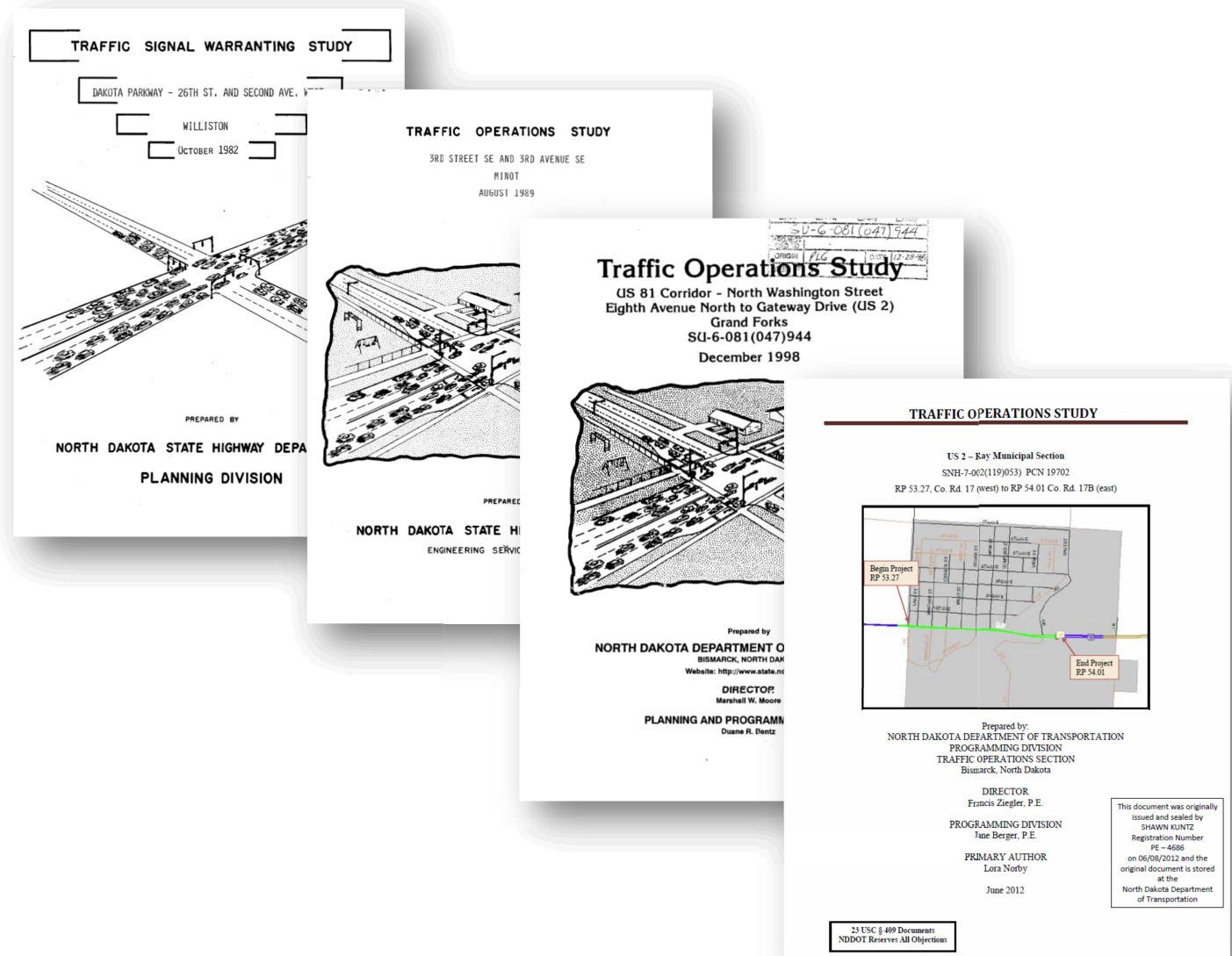


# NDDOT TRAFFIC OPERATIONS MANUAL



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**List of Acronyms and Short Names**

AADT	Average Annual Daily Traffic
DSDS	Dynamic Speed Display Sign
EPDO	Equivalent Property Damage Only
FHWA	Federal Highway Administration
FYA	Flashing Yellow Arrow
HSIP	Highway Safety Improvement Program
HSM	Highway Safety Manual
ICWS	Intersection Conflict Warning System
ITS	Intelligent Transportation Systems
LPI	Leading Pedestrian Interval
LRSP	Local Road Safety Program
MUTCD	Manual on Uniform Traffic Control Devices (2009 Edition)
NDDOT	North Dakota Department of Transportation
PCE	Passenger Car Equivalent
RCUT	Restricted Crossing U-Turn (intersection)
SHSP	Strategic Highway Safety Plan
SRSP	State Road Safety Program
TAADT	Truck Average Annual Daily Traffic
TRB	Transportation Research Board
TWSC	Two-way stop controlled (intersection)

## TRAFFIC OPERATIONS OVERVIEW

This manual describes typical NDDOT practice for traffic operations work. It is meant to be used as a guideline only and not be a substitute for engineering judgment. This manual is not meant to replace or conflict with commonly accepted references such as the MUTCD, Green Book, Highway Capacity Manual, Highway Safety Manual, Access Management Manual, etc. The checklists, flowcharts and tables were created to encourage a consistent decision making process.

Traffic operations studies provide recommendations for traffic control, need for turn lanes, lighting, signals, beacons and other safety improvements.

**NDDOT has adopted the 2009 Manual on Uniform Traffic Control Devices.** A traffic control analysis should determine whether traffic control devices are needed along the project corridor and should ensure existing devices meet current MUTCD and NDDOT standards. Traffic control devices include signs, markings, traffic signals, and flashing beacons.

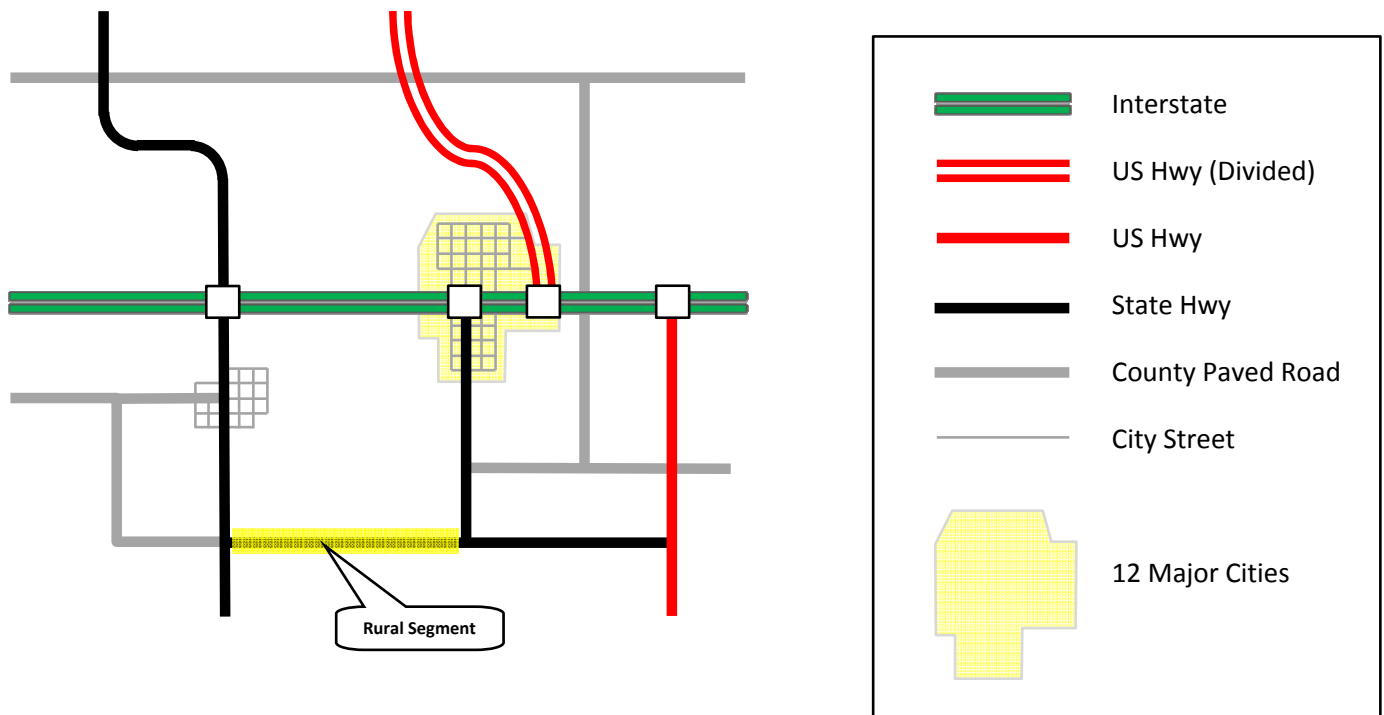
A typical traffic study should describe the following items (some items may not apply to all studies):

- Documentation and manual references, references to previous studies
- Location (project limits, roadway name, reference points, name of city, etc). A location map may be helpful to the reader. Often NDDOT will put a location map on the cover of the traffic operations study document.
- Project number/PCN (if applicable)
- Description of the proposed work
- Proposed construction year
- Identify the study intersections
- Length of study area
- Assumptions
- Summary of recommendations
- Appendix materials and support documentation
- Every page should have a 409 stamp:

23 USC § 409 Documents  
NDDOT Reserves All Objections

In 1987, Congress determined that federal record keeping requirements were subjecting state transportation agencies to inappropriate litigation and stifling the open discussion of safety issues. Congress enacted 23 United States Codes (U.S.C.), Section 409, to remedy these problems.

The following pages describe in further detail the items needed in the traffic study depending on the element being studied. These checklists can be used to write traffic studies for NDDOT projects. Often, projects are a combination of several of these elements (such as a rural highway segment includes rural intersections and horizontal curves).

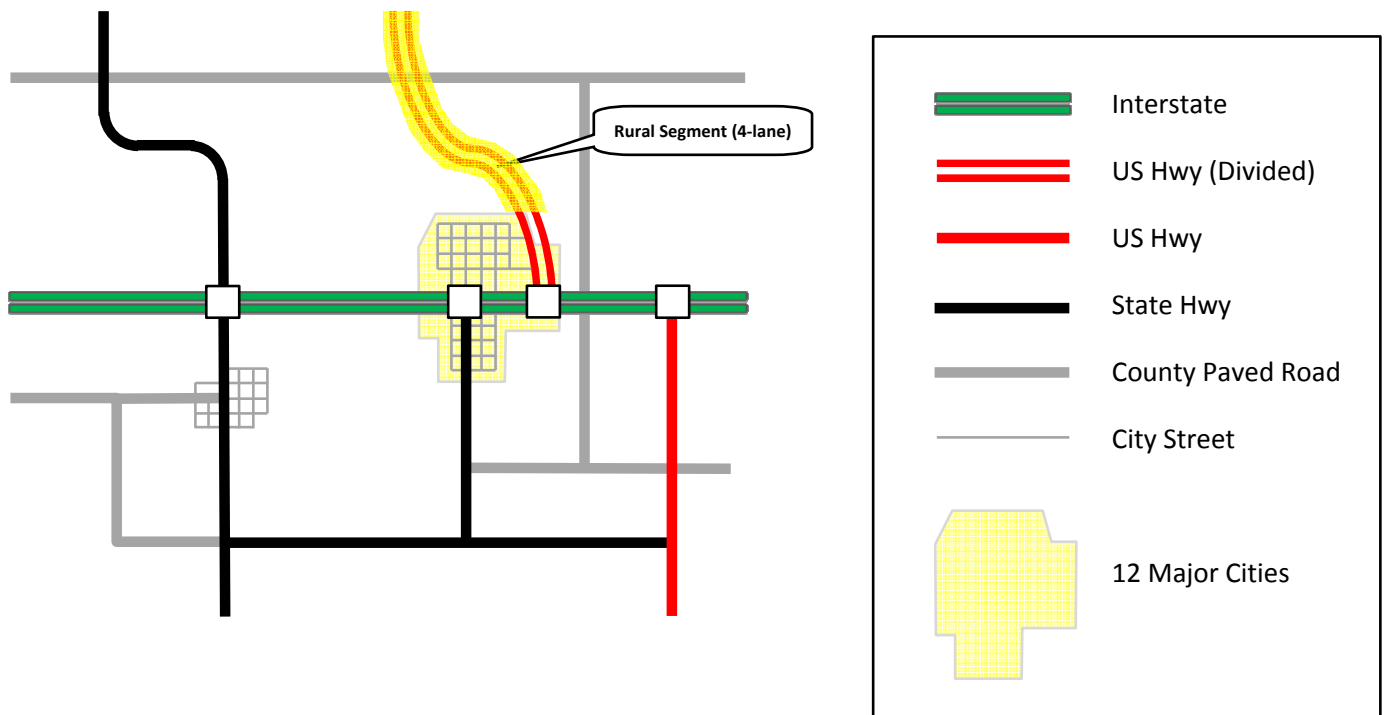
**RURAL SEGMENTS (2-LANE)**

A traffic study of a rural segment on a 2-lane highway typically contains the following:

- ☐ Traffic data – average annual daily traffic (AADT), truck average annual daily traffic (TAADT) – describe how and when it was collected, also indicate the projected 20-year forecasted traffic volumes
- ☐ Roadway speed limit(s) – describe any speed zones, provide beginning and ending reference points (on state system)
- ☐ Roadway geometry (number of lanes, presence of passing lanes, typical section, lane widths, shoulder widths, etc)
- ☐ Highway performance classification
- ☐ Functional classification
- ☐ Describe horizontal/vertical alignment
- ☐ Presence of railroad crossings
- ☐ Surrounding land use
- ☐ Capacity analysis – see chapter 15 of the HCM<sup>1</sup> for two-lane highways analysis
- ☐ Crash history and analysis
- ☐ Lighting warrants (refer to table 4 of Lighting Warrant Policy<sup>2</sup>)
- ☐ Cross reference HSIP – check SRSP or LRSP documents for recommended safety improvements of rural roadway segments based on risk assessments
- ☐ Summary of recommendations

**References:**

1. TRB, "Highway Capacity Manual 2010," December 2010.
2. NDDOT, "[Lighting Warrant Policy](#)", March 2015.

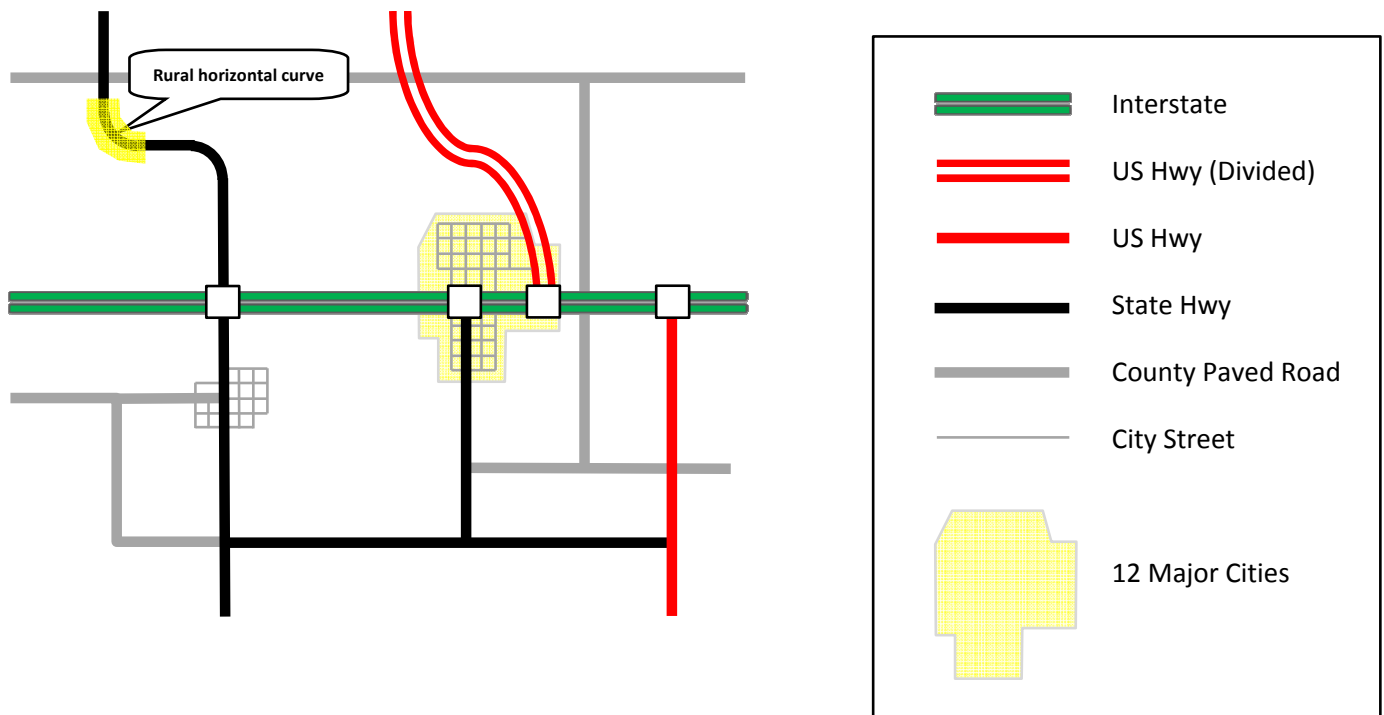
**RURAL SEGMENTS (4-LANE)**

A traffic study of a rural segment on a multi-lane highway typically contains the following:

- ② Traffic data – average annual daily traffic (AADT), truck average annual daily traffic (TAADT) – describe how and when it was collected, also indicate the projected 20-year forecasted traffic volumes
- ② Roadway speed limit(s) – describe any speed zones, provide beginning and ending reference points (on state system)
- ② Roadway geometry (number of lanes, typical section, lane widths, shoulder widths, etc)
- ② Highway performance classification
- ② Functional classification
- ② Describe horizontal/vertical alignment
- ② Presence of railroad crossings
- ② Surrounding land use
- ② Capacity analysis – see chapter 14 of the HCM<sup>1</sup> for multi-lane highways analysis
- ② Crash history and analysis
- ② Lighting warrants (refer to table 4 of Lighting Warrant Policy<sup>2</sup>)
- ② Cross reference HSIP – check SRSP or LRSP documents for recommended safety improvements of rural roadway segments based on risk assessments
- ② Summary of recommendations

**References:**

1. TRB, “*Highway Capacity Manual 2010*,” December 2010.
2. NDDOT, “[Lighting Warrant Policy](#)”, March 2015.

**RURAL HORIZONTAL CURVES**

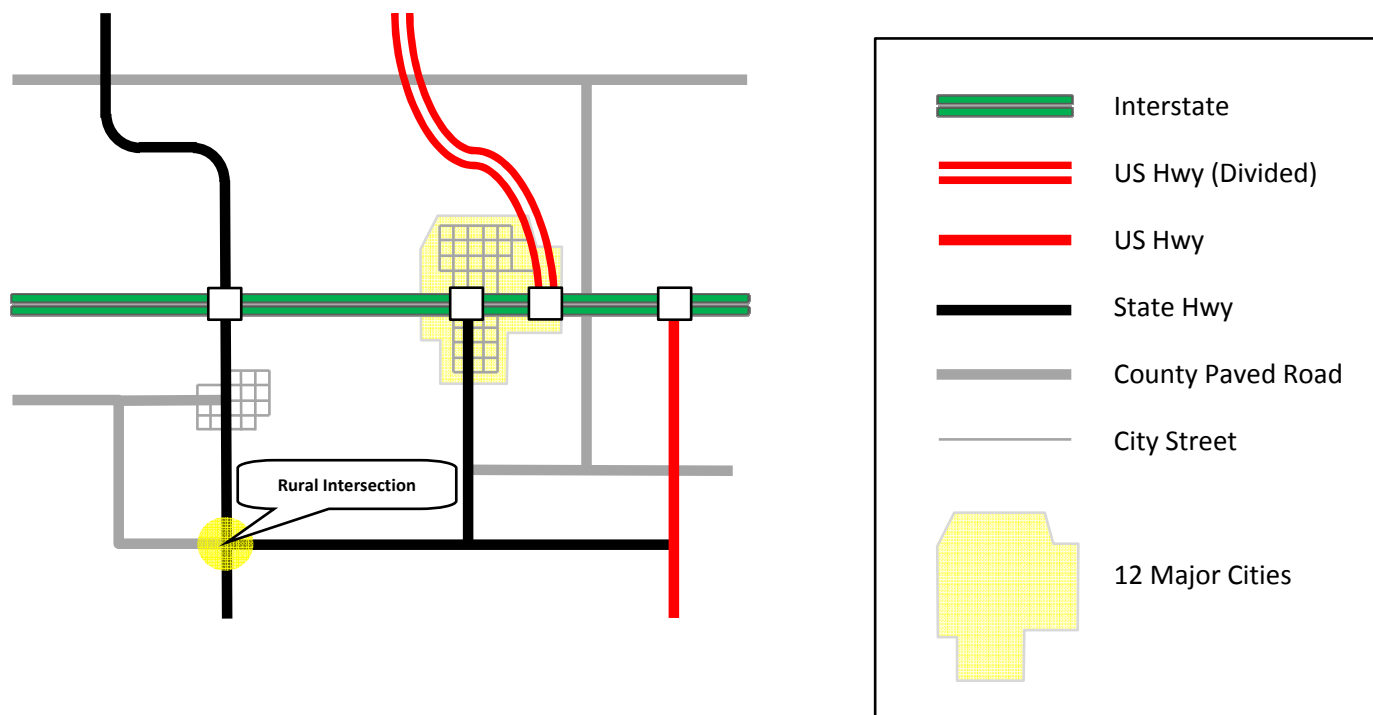
Curves are often a subset analysis of a larger traffic study for a roadway segment. Items specific to the analysis of horizontal curves in a traffic study:

- ② Curve radius and evaluation of signing based on the design manual<sup>1</sup>
- ② Presence of intersection(s) along the curve
- ② Presence of a “visual trap” (where the line of sight makes the roadway appear to continue straight but the main highway actually has a curve)
- ② Cross reference HSIP – check SRSP or LRSP documents for recommended safety improvements of rural horizontal curves based on risk assessments

For curves less than 1500 foot radius, chevron signs and curve signs are strongly recommended. Chevrons may also be used for larger curves based on engineering judgment. For example, where there is a “visual trap”. Other curves should be evaluated based on the design.

**References:**

1. NDDOT, “[Design Manual](#)”. August 2013. (Section III-09.04)

**RURAL INTERSECTIONS**

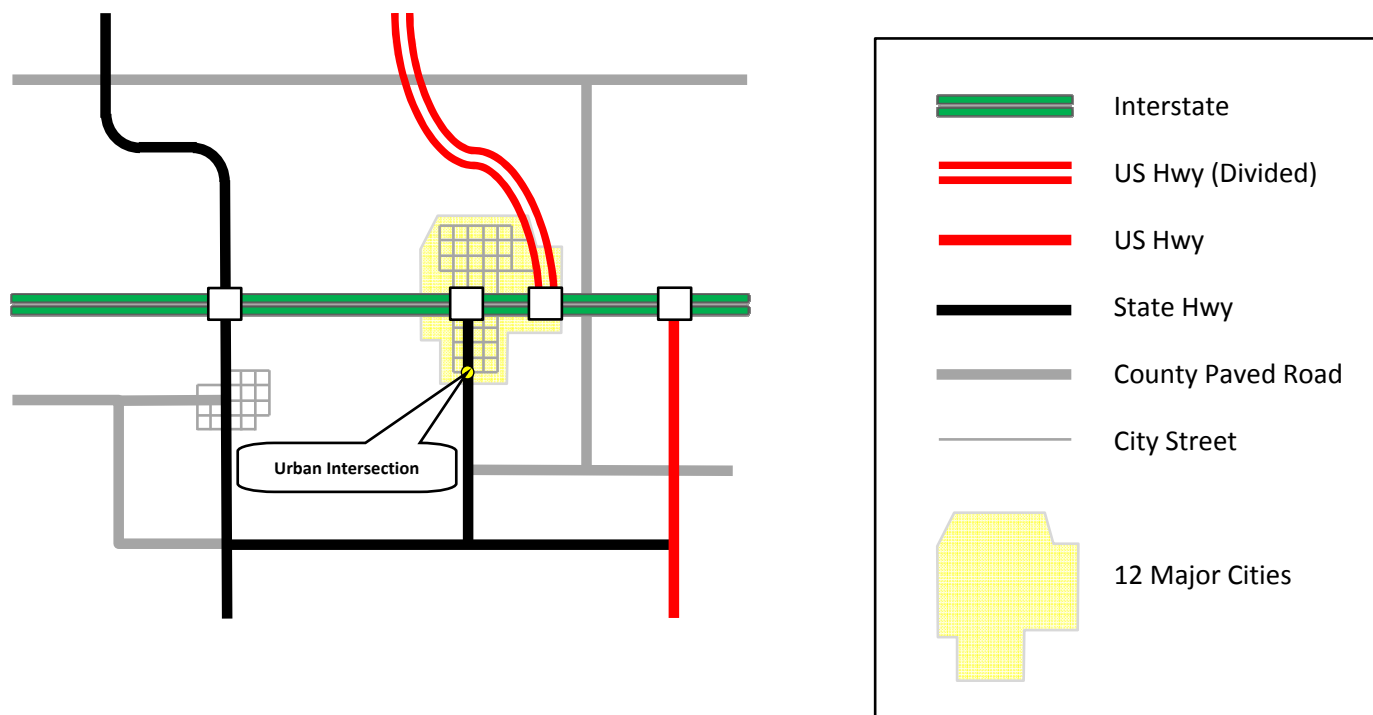
Rural intersections may be a subset of a larger traffic study for a roadway segment or are sometimes their own study. Intersections that should be studied are state highways, CMC routes, or paved county roads. Items specific to the analysis of rural intersections in a traffic study:

- ② AADT and TAADT on all approaches. A “turning movement diagram” that shows the daily volumes of through and turning movements is necessary
- ② Existing type of intersection control (TWSC, AWSC, Signal, Roundabout, etc)
- ② Intersection capacity analysis – see chapter 19 of the HCM<sup>1</sup> for TWSC, chapter 20 for AWSC, chapter 21 for roundabouts, chapter 18 for signals
- ② Intersection related crash history and analysis
- ② Intersection sight distance – Even if the crash history does not show a problem with the intersection sight distance, all intersections that are studied in the traffic operations report should have an evaluation of the sight triangles. For more details on evaluating intersection sight distance, refer to the “Green Book”. Typically NDDOT Traffic Operations will evaluate the sight distance informally using GIS software. Any methods of evaluating sight distance should be described in the traffic study (including assumptions made).
- ② Turn lanes (need to add left or right turn lanes, determine length of turn lanes)
- ② Recovery Approaches (or need for them)
- ② Signal Warrants (only for high volume locations)
- ② Lighting warrants (refer to tables 5 and 6 of the Lighting Warrant Policy<sup>2</sup>)
- ② Cross reference HSIP – check SRSP or LRSP documents for recommended safety improvements of rural intersections based on risk assessments
- ② Summary of recommendations

NDDOT has adopted a policy<sup>3</sup> on the installation of Do Not Enter and Wrong Way signs at stop controlled divided highway intersections.

**References:**

1. TRB, “*Highway Capacity Manual 2010*,” December 2010.
2. NDDOT, “[Lighting Warrant Policy](#)”, March 2015.
3. NDDOT, “*Installation of Do Not Enter and Wrong Way signs at Stop Controlled Divided Highway Intersections*”, July 2011.

**URBAN INTERSECTIONS**

Items specific to the analysis of urban intersections in a traffic study:

- ☐ Existing type of intersection control (TWSC, AWSC, Signal, Roundabout, etc)
- ☐ AADT and TAADT on all approaches. A “turning movement diagram” that shows the daily volumes of through and turning movements is necessary
- ☐ If the intersection is being evaluated for signal warrants, a turning movement count at the intersection for a minimum of 12 hours is required. Typically, NDDOT collects a 16-hour turning movement count that begins at 6:00am and ends at 10:00pm. This timeframe will capture the eight highest traffic volume hours at most intersections that is needed for the MUTCD traffic volume warrants.
- ☐ Intersection capacity analysis – see chapter 19 of the HCM<sup>1</sup> for TWSC, chapter 20 for AWSC, chapter 21 for roundabouts, chapter 18 for signals
- ☐ Intersection related crash history and analysis
- ☐ Intersection sight distance – Even if the crash history does not show a problem with the intersection sight distance, all intersections that are studied in the traffic operations report should have an evaluation of the sight triangles. For more details on evaluating intersection sight distance, refer to the “Green Book”. Typically NDDOT Traffic Operations will evaluate the sight distance informally using GIS software. Any methods of evaluating sight distance should be described in the traffic study (including assumptions made).
- ☐ Turn lanes (need to add left or right turn lanes, determine length of turn lanes)
- ☐ Signal Warrants (where necessary)
- ☐ Lighting warrants (refer to tables 5 and 6 of the Lighting Warrant Policy<sup>2</sup>)
- ☐ Cross reference HSIP – check LRSP document for recommended safety improvements of urban intersections based on risk assessments
- ☐ Summary of recommendations



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## OTHER TYPES OF TRAFFIC STUDIES

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### Traffic impact studies for new developments

Special traffic studies are needed when there is a development proposed adjacent to or near the state highway system<sup>1</sup>. Typically these studies include many of the items listed above but also require a calculation of the trip generation. Trip generation numbers are added to existing traffic volumes and the impact of the proposed development to the system is analyzed in these studies.

### Temporary Traffic Control

A “work zone safety and mobility<sup>2</sup>” analysis should be done for significant projects. A project is considered “significant” where it exceeds an estimated \$3,000,000 in cost and is on the urban regional system that either goes through a Metropolitan Planning Organization (MPO) boundary or city over 25,000 in population. Traffic operations will analyze the existing level of service of the facility and compare that with the level of service under work zone traffic control. The traffic control plan is acceptable if the level of service is no less than two grades lower than the existing and traffic delays are less than 15 minutes.

### Highway Safety Improvement Program<sup>3</sup>

Infrastructure-related highway safety improvements are developed through the Highway Safety Improvement Program (HSIP). The program’s goal is to reduce fatalities and serious injuries. Applications for HSIP projects come from NDDOT districts, MPO’s, cities, counties and tribal governments. Potential HSIP projects may require special traffic studies to evaluate the proposed safety improvements. Projects can be created to address crash problems on a particular roadway or at intersections (reactive). Projects may also be developed on a “systemic” basis where a roadway or intersection has a high number of risk elements (proactive). These elements may lead to a potential for serious injury or fatality crashes even if there is little or no evidence of crashes.

### References:

1. NDDOT, “*Guidelines for New Development Adjacent to the ND State Highway System*”, June 2012.
2. NDDOT, “[Workzone Safety & Mobility](#)”, February 2007.
3. NDDOT, “*Highway Safety Improvement Program Implementation Plan*”, March 2015 (PENDING APPROVAL).

**CAPACITY ANALYSIS**

Capacity analysis should follow the procedures of the Highway Capacity Manual<sup>1</sup>. The author should note any software program used during the capacity analysis. NDDOT uses HCS and/or Synchro-Simtraffic. However, NDDOT does not adopt or recommend any specific software for capacity analysis.

For study intersections with turning movement data, NDDOT uses the four highest consecutive 15-minute periods as the peak hour.

Typical items from the capacity analysis:

- Determine the number of traffic lanes needed, including the need for any turning lanes (see turn lane section) or passing lanes.
- Recommend the type of intersection traffic control (two-way stop, all-way stop, signal, roundabout, etc)
- Establish signal phasing, timing, and coordination needs (if applicable, see traffic signals section)
- Identify operational problems (provide guidance to relocate or close driveways near intersections, consolidate driveways or other access points, etc)
- Establish the “level of service” (LOS) for each intersection to be studied and when appropriate, the entire arterial

The designing agency should design the facility to an overall LOS that meets or exceeds the values as shown below.

<b>Functional Class</b>	<b>Rural</b>	<b>Urban &amp; Suburban</b>
Interstate	LOS B	LOS C
Principal Arterial	LOS C	LOS D
Minor Arterial	LOS C	LOS D
Collector	LOS C	LOS D
Local	LOS D	LOS D

The purpose of the capacity analysis is to determine a recommended geometric design that meets minimum LOS under 20-year projected traffic. Normally the report discusses the study intersections’ operation with the proposed lane geometry under the 20-year projected volumes. Some studies may require analysis of both existing and proposed lane geometry. If an intersection does not currently meet signal warrants, but is likely to with the future volumes, a signalized capacity analysis (on proposed geometry) of the 20-year projected volumes should be included in the study. This does not mean a signal has to be a recommendation in the study, but this will inform the reader that the proposed geometry (turn lanes) will be adequate for future conditions. If a two-way stop control intersection is calculated at LOS F for the minor street approaches, and the likelihood of meeting signal warrants within 20 years is low, it is not necessary to determine the necessary geometry to meet the LOS value shown in the table.

Projected traffic volumes are based on a yearly growth factor that may be obtained from the NDDOT Roadway Data Section. In urban MPO areas, traffic volumes may be obtained from citywide traffic models.

For rural areas, a 20-year volume projection can be used for capacity analysis. Note that two-way stop controlled rural expressway intersections tend to experience safety issues long before they experience congestion<sup>2</sup>.

**References:**

1. TRB, “*Highway Capacity Manual 2010*,” December 2010.
2. TRB, “*NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways*”, 2010. (page 149)

## CRASH ANALYSIS

The evaluation of crash history may help to identify existing problems. The crash analysis section of the study may identify alternatives to help reduce potential crashes. Recommendations such as installing rumble strips, adding or modifying signing/stripping, changing horizontal/vertical alignment are examples of possible countermeasures. Safety improvements must consider all road users (pedestrians, bicycles, etc).

Traffic operations studies require the collection of crash data. For local governmental agencies and consultants this data will be provided by NDDOT using the email request format shown below:

I am requesting crash data for the past X years for X Avenue from X Street to X Street and all links in between (see attached map).

I recognize this crash data is considered to be exempted from disclosure pursuant to 23 USC § 409, and can be used only with the understanding that the City of X or its agents will not release or transfer it, nor will it be used for anything other than the intended purpose as a part of a safety study or safety improvement project.

This data will be used by our staff with the City of X, and/or acting as its agent, in the development of a study.

Several crash analysis items that are discussed in a traffic study:

- Beginning and ending dates of crash data gathered (Use 5 years for rural locations and a minimum of 3 years for urban locations)
- Total number of crashes
- Breakdown of the common crash types (how many angle, rear-ends, etc.)
- Describe crash patterns relating to weather, roadway conditions, light vs. dark, etc.
- Crash summary sheets, statistics, intersection crash diagrams (usually included as an appendix)
- Possible countermeasures
- Note if the study area is listed on any NDDOT crash listings – rural intersection high crash list or urban intersection high crash list,
- Indicate severity of the segment(s) referenced from the latest state highway segment crash map. This map shows the weighted crashes per mile in one of four categories (0-10, 10-25, 25-40, 40-265).
- Highway Safety Manual<sup>1</sup> expected number of crashes (optional)

### References:

1. AASHTO, "Highway Safety Manual", 2010.

## LIGHTING

The traffic study should indicate need for new lighting or upgrades to existing lighting. Refer to NDDOT Lighting Warrant Policy<sup>1</sup> to determine where lighting is needed.

### Classification of Roadways to be used for Lighting Analysis<sup>2</sup>

Outside of the 12 major cities:

- Where the current AADT exceeds 5,000 for any roadway section within a city, the roadway shall be considered a principal arterial  
Where the current AADT exceeds 2,500 for any roadway section within a city, the roadway shall be considered a collector street
- All other roadways shall be classified as local streets.

There may be conditions under which somewhat different illuminating levels are desirable and/or necessary that those recommended with a specified roadway-street classification.

Lighting design is based on AASHTO guidelines<sup>3</sup>.

### Guidelines for the Installation of Banners on Light Standards

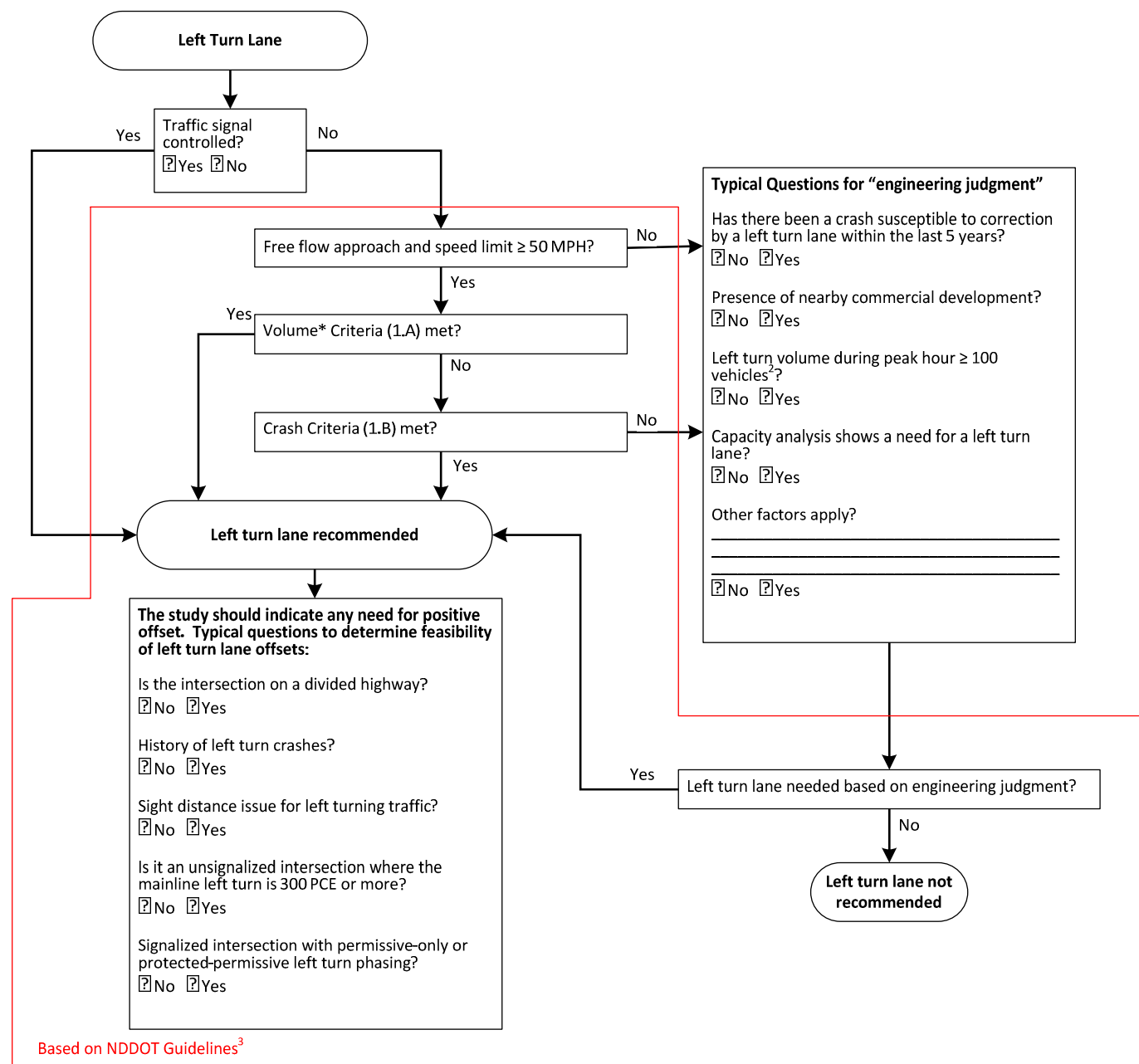
- Banners cannot interfere with any official traffic control devices.
- Banners must not look like a traffic control device.
- Under the Highway Beautification Act of 1965, it is illegal for any private or commercial business to advertise on highway right-of-way. The banners can not contain any form of advertising for private or commercial business.
- There are no specified mounting height requirements for banners on light standards at this time. A distance of 10 feet from the bottom of the banner to allow for pedestrians and vehicles to pass under is recommended. Mounting brackets should be hinged and allow for rotation if the banner is struck.
- The maintenance of the banners and mounting hardware would be the responsibility of the local road authority. The NDDOT will not be responsible for any banners.
- The manufacturer or the owner of the light standard/utility pole must verify that the pole is structurally sound to support the banner.
- Recommend that they only be installed within city limits and in a reduced speed zone.

### References:

1. NDDOT, "[Lighting Warrant Policy](#)", March 2015.
2. NDDOT, "*Operating Procedure Memorandum: Classification of Roadways to be used for Highway Lighting*", June 1977.
3. AASHTO, "*Roadway Lighting Design Guide*", October 2005.

**LEFT TURN LANE**

In designing an intersection, left-turning traffic should be removed from the through lanes, whenever practical<sup>1</sup>. Left turn lanes should be considered at the planning and preliminary design stages of any new signalized intersection<sup>2</sup>. However, it is not cost effective to install a left turn lane at every roadway intersection. The flowchart below may be used to determine whether a left turn lane should be recommended in the traffic study. The flowchart is primarily based on the NDDOT guidelines<sup>3</sup>.



\*For construction project traffic operations studies, use the projected 20 year volumes. For other turn lane requests, use existing traffic count volumes.

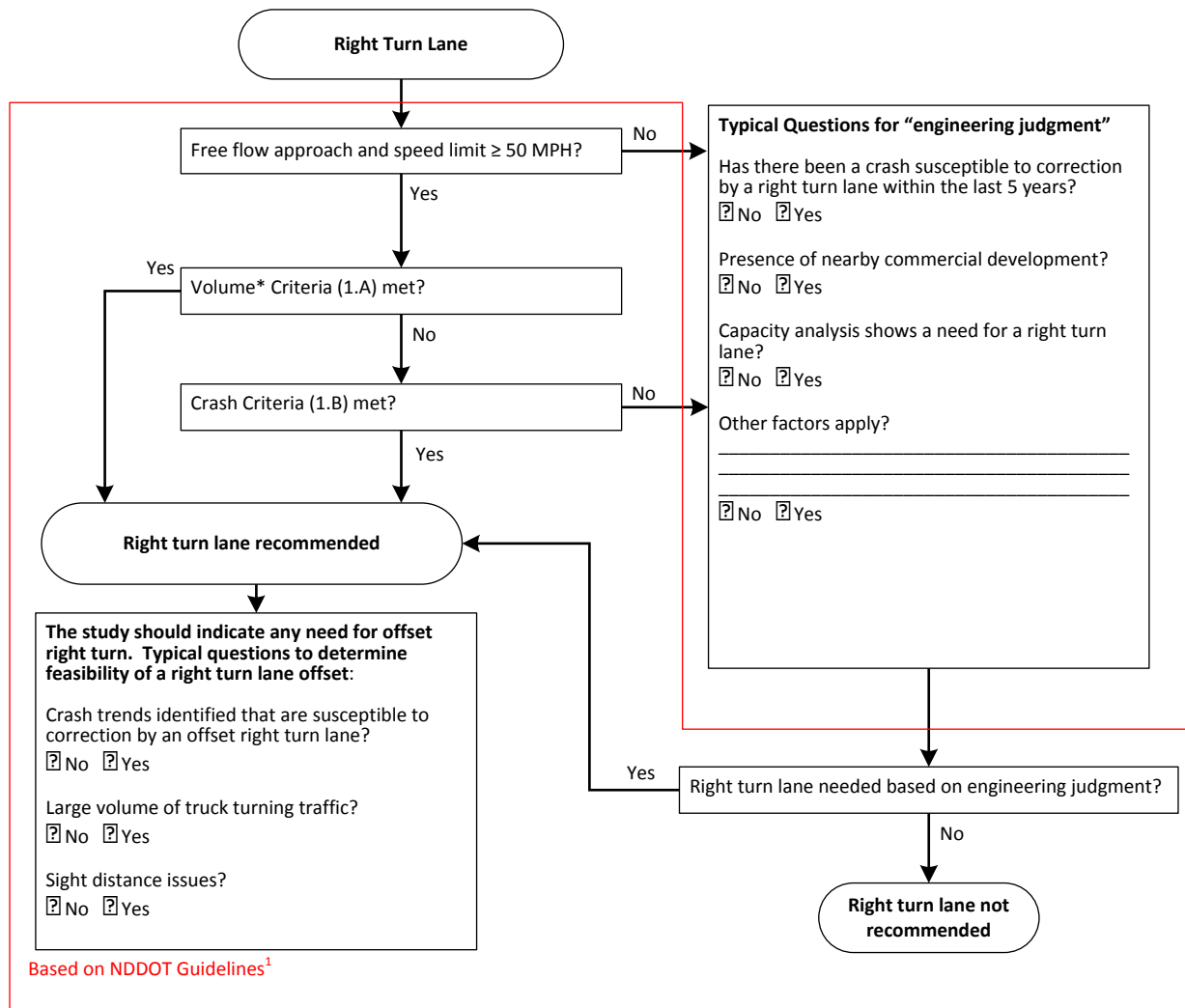
Dual left turn lanes should be considered if the left turn volumes exceed 300 vehicles per hour<sup>1</sup>. Dual *receiving* lanes are necessary and need to be at least 15 feet wide where dual left turn lanes are used.

**References:**

1. AASHTO, "A policy on Geometric Design of Highways and Streets," 2011 (Section 9.7.3)
2. TRB, "NCHRP Report 279: Intersection Channelization Design Guide", November 1985. (page 48)
3. NDDOT, "[Guidelines for the Installation of Turn Lanes along State Highways](#)," July 2014.

**RIGHT TURN LANE**

The flowchart below may be used to determine the whether a right turn lane should be recommended in the traffic study. The flowchart is primarily based on the NDDOT guidelines<sup>1</sup>.



\*For construction project traffic operations studies, use the projected 20 year volumes. For other turn lane requests, use existing traffic count volumes.

**References:**

1. NDDOT, "[Guidelines for the Installation of Turn Lanes along State Highways](#)," July 2014.

**TURN LANE LENGTH AT UNCONTROLLED APPROACHES**

An uncontrolled turn lane is defined as any turn lane in which no traffic signals or signs are used to control traffic movement within the turn lane<sup>1</sup>. Details on the design of the turn lane geometry can be found in the NDDOT Design Manual Section III-03.05.01. The storage distance (L4) is the most important value that is needed by readers of the traffic operations study. The storage length procedure is described below. Other turn lane design elements (L1, L2, L3, L5 from the NDDOT Design Manual<sup>1</sup>) may be necessary in the development of a traffic study. Their calculation is also described below.

**L1:** **Taper** – The L1 distance is based on the design speed, see table below.

DESIGN SPEED	30	35	40	45	50	55	60	65	70
TURN LANE TAPER	8:1	12:1	12:1	12:1	15:1	15:1	15:1	15:1	15:1
TAPER LENGTH (L1)	96	144	144	144	180	180	180	180	180

**L2:** **Deceleration** – The L2 distance is based on the design speed, see table below.

DESIGN SPEED	30	35	40	45	50	55	60	65	70
DECELERATION (L2)	75	100	150	200	265	335	430	530	640

**L3:** **Design distance** – This length is equal to the sum of the L1 and L2 distances.

**L4:** **Storage** – For right turn lanes, this distance is 0 ft. For left turn lanes, this distance is typically the highest of the following:

- The 95<sup>th</sup> percentile queue distance of left turning vehicles (based on the capacity analysis)
- Value from the table below.

<i>Left Turn Storage Distance in feet for 2-Lane Highway (4-Lane Highway in parentheses)</i>				
LEFT TURNING TRUCK VOLUME (trucks per day) ↓	VOLUME (AADT) ON ROADWAY APPROACH WITH TURN LANE			
	< 5000	5,000 - 10,000	10,000 - 20,000	> 20,000
<50	100 (100)	100 (100)	100 (100)	150 (125)
50 - 100	100 (100)	100 (100)	125 (100)	200 (175)
100 - 150	100 (100)	125 (100)	150 (125)	250 (225)
150 - 200	125 (100)	150 (125)	175 (150)	350 (325)
200 - 250	150 (125)	175 (150)	200 (175)	450 (300)
250 - 500	175 (150)	200 (175)	400 (300)	700 (500)
500 - 1000	275 (250)	450 (400)	700 (600)	800 (700)
1000 - 1500	425 (400)	650 (600)	800 (700)	900 (800)
> 1500	500 (450)	700 (650)	900 (800)	1000 (900)

This left turn storage distance table was developed by NDDOT as a way to account for longer queues due to heavy truck turning movements. It was based on experiments modeling a wide range of traffic scenarios using Simtraffic. A storage length of 100 feet has been selected by NDDOT to be the minimum distance to provide for all left turn lanes.

**L5:** **Transition Taper Length** – Where the design speed is 40 mph or less, then  $L5 = WS^2/60$ , otherwise  $L5 = WS$  (W = width of transition, S = design speed)

The study should indicate if a left turn lanes are to be designed with a positive offset and if right turn lanes are to be designed with an offset (these items relate to providing proper sight distance).

**References:**

1. NDDOT, "[Design Manual](#)," July 28, 2014. (Section III-03.05.01)

**TURN LANE LENGTH AT CONTROLLED APPROACHES**

For a turn lane on an approach that is controlled by a stop sign, yield sign or traffic signal, the traffic operations study will indicate the recommended “full-width length” of the turn lane<sup>1</sup>.

**Traffic Signal**

For turn lanes at a signalized intersection, the full-width length recommendation is typically the highest of the following:

- The 95<sup>th</sup> percentile queue distance of *turning* vehicles (based on the capacity analysis)
- The average queue distance of the *adjacent* through lane (based on the capacity analysis)
- 100 feet
- Deceleration distance from the table below.

DESIGN SPEED	30	35	40	45	50	55	60	65	70
DECELERATION	75	100	150	200	265	335	430	530	640

**Stop Sign or yield sign**

For turn lanes at a stop sign or yield sign controlled approach, the full-width length recommendation is typically the highest of the following:

- 100 feet
- 95<sup>th</sup> percentile queue distance of turning vehicles (based on the capacity analysis)

Most turn lanes are 100 feet full-width length at stop or yield controlled approaches. If the capacity analysis is LOS F, the 95<sup>th</sup> percentile length may be much longer and is not a practical recommendation. If it is likely that a traffic signal would be warranted within 20 years, the recommended full-width length may be determined using the signalized approach method.

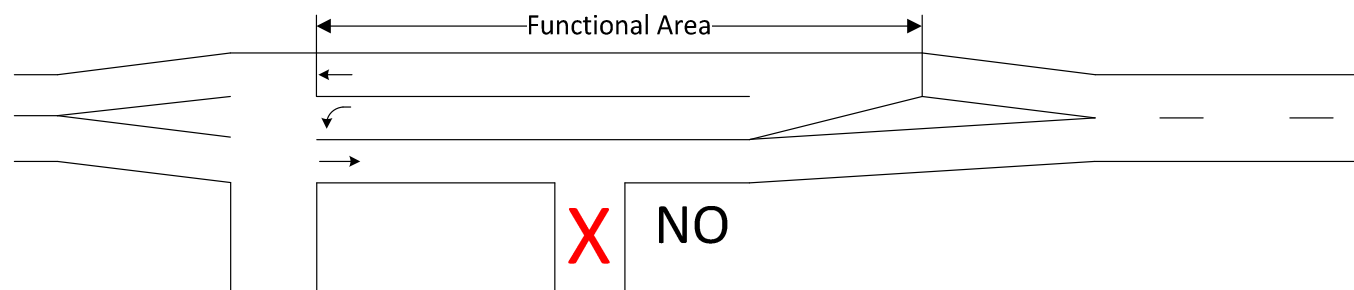
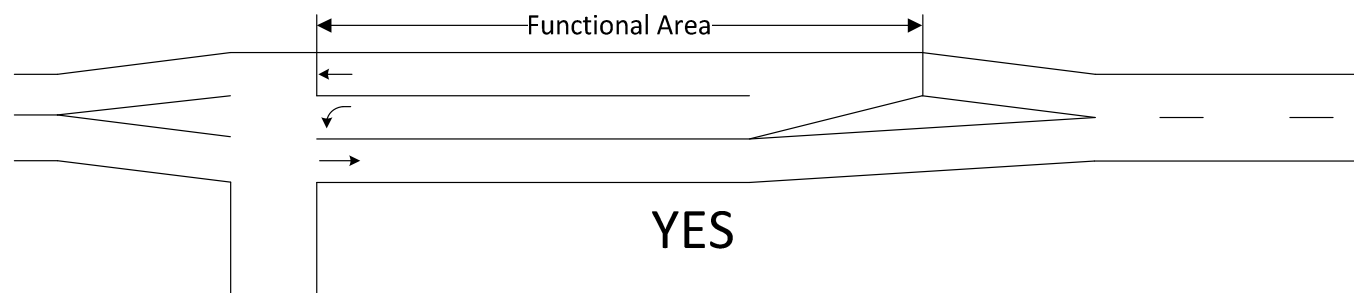
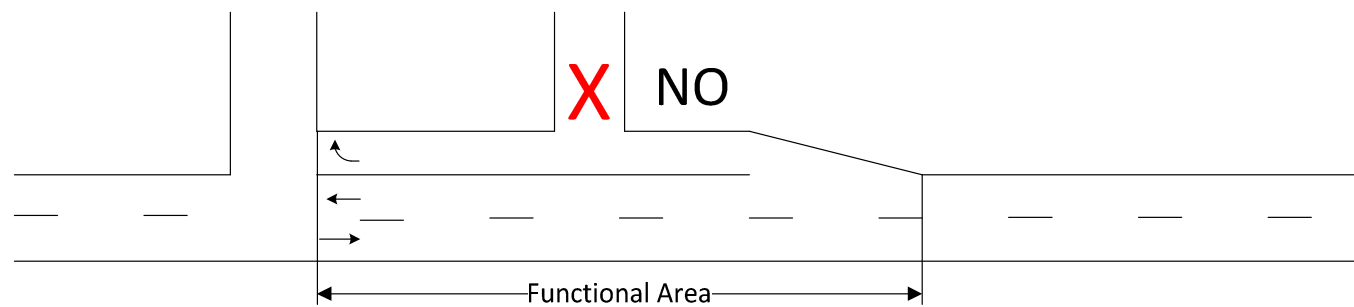
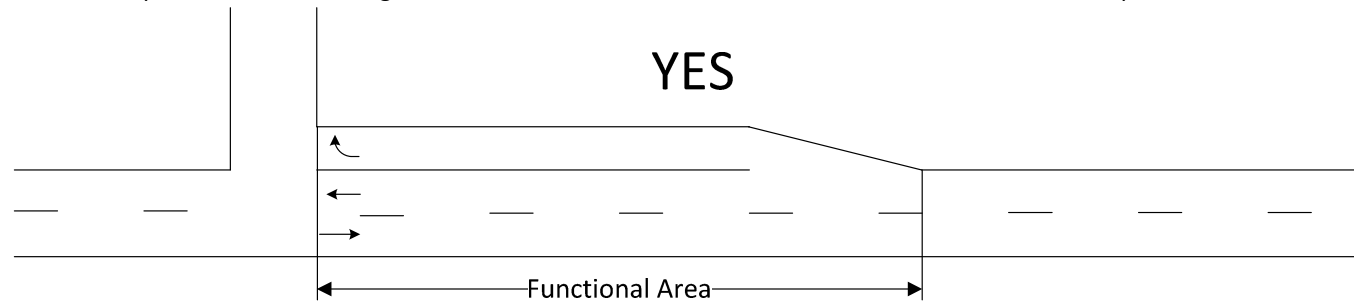
**References:**

1. NDDOT, “[Design Manual](#),” July 28, 2014. (Section III-03.05.01)



## ISSUES TO CONSIDER WITH TURN LANE RECOMMENDATIONS

The NDDOT practice is to discourage accesses within the functional area of the turn lanes. Some examples are shown below.



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**ACCELERATION LANES**

An acceleration lane is an auxiliary or speed-change lane that allows vehicles to accelerate to highway speeds before entering the through-traffic lanes of a highway<sup>1</sup>.

NDDOT will consider installation of a median acceleration lane (MAL) at intersections on divided highways where all of the following criteria<sup>2</sup> are met:

1. There is a significant history of rear-end or sideswipe crashes
2. Intersection sight distance is inadequate for left-turning traffic entering the divided highway
3. There is a high volume of left-turning trucks (75 or more per day) entering the divided highway.

Acceleration lanes are generally not installed in urban areas on non-interstate roadways. The NDDOT has found through past history that they are ineffective because motorists generally choose not to use them<sup>3</sup>.

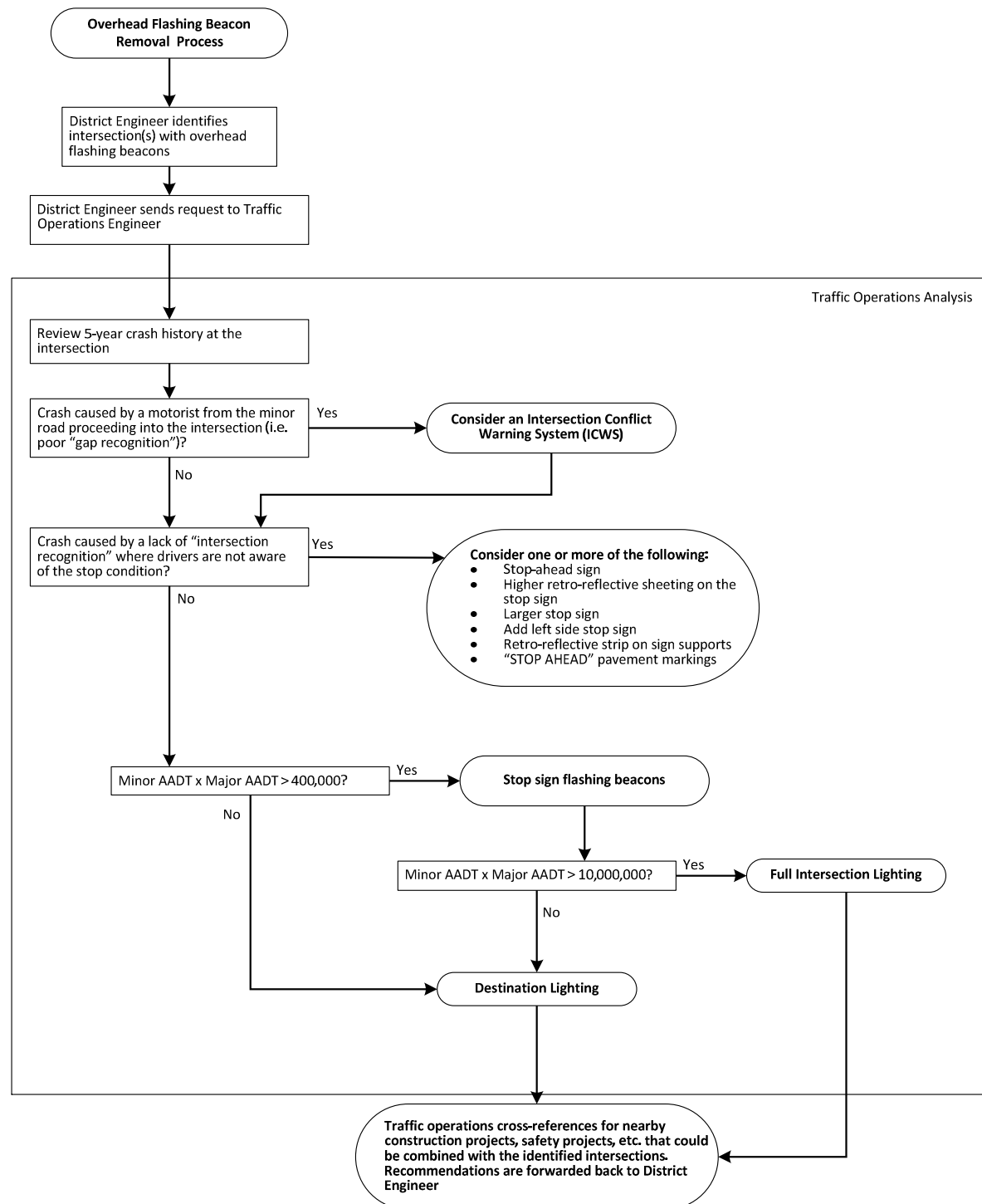
**References:**

1. TRB, "[NCHRP Report 500 Volume 5: A Guide for Addressing Unsignalized Intersection Collisions](#)", 2003. (page V-23)
2. TRB, "[NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways](#)", 2010. (page 107)
3. NDDOT, "Memorandum: 6<sup>th</sup> Ave SW Approach", January 4, 2005.

**OVERHEAD FLASHING BEACON**

Recent information obtained from NDDOT engineering and safety partners is leading the department away from the use of overhead flashing beacons. Review of existing information indicates no proven crash reduction after installation of these devices. Other countermeasures are available to reduce intersection crashes that have the potential to be more effective.

A traffic study that includes an intersection with an existing overhead mounted flashing beacon should recommend its removal. The process shown below describes the process for removing existing overhead flashing beacon systems.

**References:**

1. NDDOT, "Removal of Overhead Flashing Beacons", April 2015 (PENDING APPROVAL).

**TRAFFIC SIGNALS**

The decision on whether or not to do a signal warrant analysis at a study intersection should be based on engineering judgment. Intersections where the product of the highest major road AADT times the highest minor road AADT is greater than 20,000,000, it is possible that MUTCD warrants may be met. This “rule of thumb” may be used for planning purposes but should not be used to recommend signal installation. Traffic signals in rural areas are discouraged for several reasons including violation of driver expectations and difficulty in servicing and maintaining signals in remote locations<sup>1</sup>.

Any recommendation for installation of a traffic signal should have documentation on what MUTCD warrants are met. The NDDOT form SFN 7924 should be used to document a signal warrant analysis. This form may be supplemented with printouts from any software or spreadsheet programs used to analyze the warrants. Meeting signal warrants does not in itself require the installation of a traffic signal. If an intersection does not meet signal warrants based on current traffic but is close, it is helpful to decision makers if the author identifies the approximate year a signal may be needed.

Traffic studies that examine existing signalized intersections or where a traffic signal is recommended typically supply the following information:

- Existing signal timing (cycle length, split times, yellow timing, all-red timing, pedestrian crossing timing and coordination settings such as offset, etc.).
- Analysis of optimized timings for current traffic and future traffic on the proposed roadway geometry.
- Recommended signal timing plan(s).
- Signal progression plans (time-space diagrams) for coordinated signals, need for interconnection.
- Recommended left turn type (permissive, protected-permissive, protected).
- Need for new controller or detection equipment

When determining splits for coordination timings and time-space diagrams, the splits consist of the green, yellow, and all-red time. Splits are programmed into the controller as whole numbers only, no decimals. To prevent unexpectedly short green times, the green portion of the split should be at least 8 seconds, even for left turn movements. Please note, the green portion of the split is different than the “Min Green” setting in the controller. With coordinated-actuated operations, low volume minor movements can still gap out prior to using the entire green portion of the split.

A traffic study of an existing signalized intersection typically would not need to be analyzed for signal warrants. If it is questioned whether the signal in-place should be removed, follow ITE’s “Guidelines for the Activation, Modification, or Removal of Traffic Control Signals<sup>2</sup>”.

**NDDOT phase number convention**

Where the major road runs east-west:

φ1 ↶	φ2 →	φ3 ↷	φ4 ↑
φ5 ↷	φ6 ←	φ7 ↶	φ8 ↓

Where the major road runs north-south:

φ1 ↶	φ2 ↓	φ3 ↷	φ4 →
φ5 ↷	φ6 ↑	φ7 ↶	φ8 ←

Note: On major north-south roads in the City of Minot, use phase 1 for SBL, phase 2 for NB, phase 5 for NBL, phase 6 for SB.

**Left turn phase type**

Determination of the left turn phasing type should be based on the flowchart from figure 4-11 of the Signal Timing Manual<sup>3</sup>. The NDDOT allows the use of flashing yellow arrows which allow more flexibility for left turn phasing.

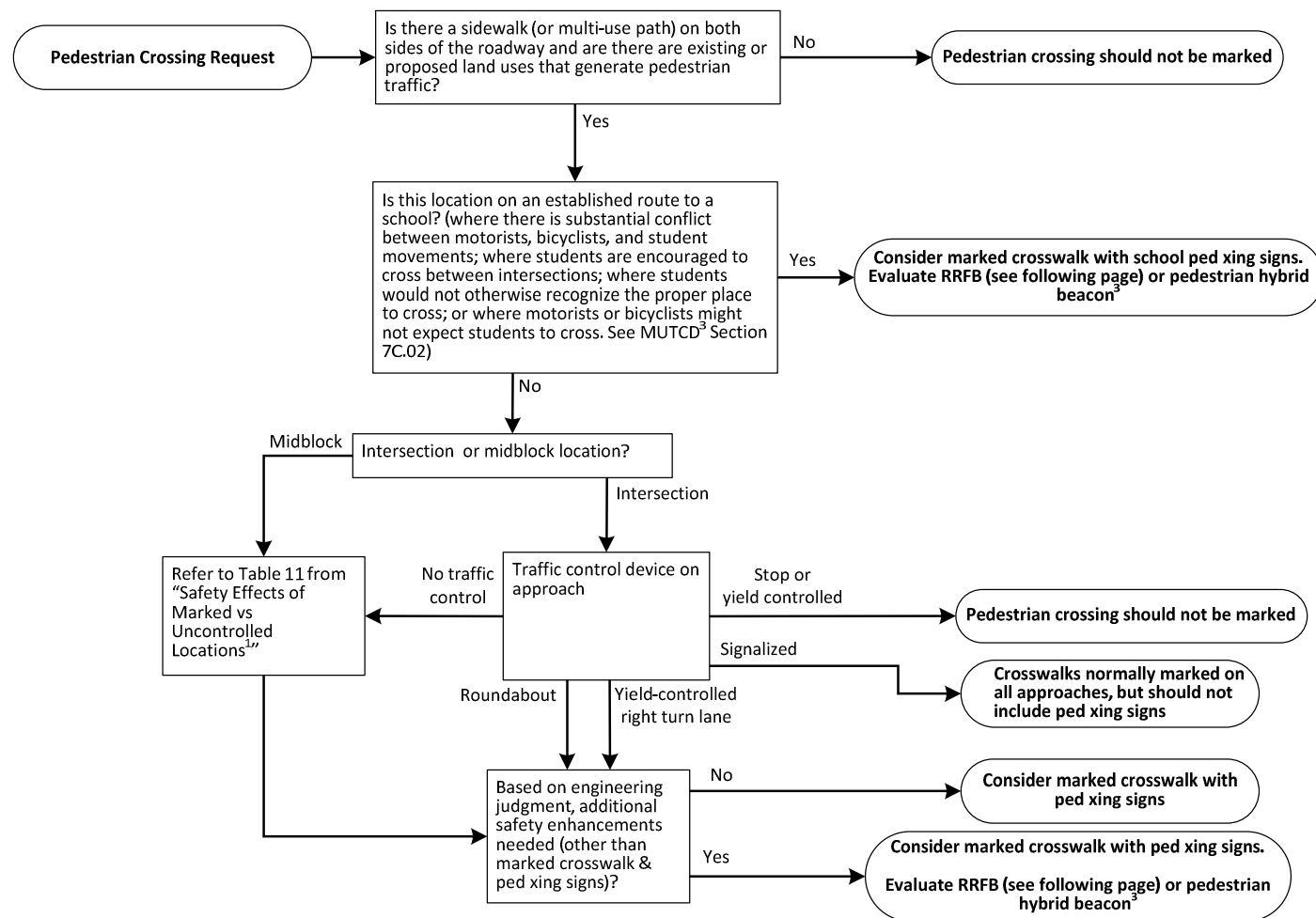
**References:**

1. TRB, “[NCHRP Report 650: Median Intersection Design for Rural High-Speed Divided Highways](#)”, 2010 (page 1)
2. ITE, “[Guidelines for the Activation, Modification, or Removal of Traffic Control Signals](#)”, 2005.
3. FHWA, “[Signal Timing Manual](#)”, June 2008.

**PEDESTRIAN CROSSWALKS**

An engineering study is performed before a marked crosswalk is installed at a location away from a traffic signal or an approach controlled by a stop or yield sign. A city or local governmental agency must submit the request to ensure they support the project, because they will be required to assume the maintenance of the improvement after it is installed. After a request for a pedestrian facility is submitted to NDDOT, traffic operations staff will review the request to ensure the location meets guidelines for installing a pedestrian crossing. Typically this review involves looking at the number of pedestrians crossing the roadway, the width of the roadway, sidewalk connectivity leading to and from the proposed location and existing nearby pedestrian crossings.

A typical crosswalk consists of two 6" white lines<sup>2</sup>. A continental style crosswalk may also be used when extra emphasis is needed; such as for midblock crosswalks, crosswalks across uncontrolled roadways, or crosswalks across a yield-controlled right turn lane at a signalized intersection (see continental crosswalk detail—NDDOT standard drawing D-762-1).

**References:**

1. FHWA, ["Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations"](#), September 2005.
2. NDDOT, ["Design Manual"](#), July 28, 2014. (Appendix III-10B)
3. FHWA, ["Manual on Uniform Traffic Control Devices"](#), 2009.

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**RECTANGULAR RAPID FLASHING BEACONS (RRFB)**

A rectangular rapid flash beacon (RRFB) is a device using flashing LEDs to provide a high-visibility strobe-like warning to drivers when pedestrians use a crosswalk. The RRFB may be placed below the pedestrian crossing sign and above the arrow indication pointing to the crossing. The (RRFB) may be used in conjunction with pedestrian crossing or school crossing signs. The RRFB is a pedestrian actuated device which is an essential aspect of its effectiveness. RRFB used in conjunction with pedestrian crossing or school crossing signs are used sparingly and only when there is a need for additional emphasis.

The decision to use an RRFB must be based on engineering analysis of the location conditions. Typical characteristics of potential locations for RRFBs:

1. Midblock crossing
2. Sight distance concern
3. Site with unexpected pedestrian crossings
4. Multiple threat crash possibility (i.e. crossing with four or more lanes)
5. AADT greater than 10,000
6. Uncontrolled intersection approaches
7. Speed limit is 40mph or greater

An RRFB functions as a warning beacon to supplement a W11-2 (pedestrian) or S1-1 (school) crossing warning sign with a diagonal downward arrow (W16-7) plaque, located at or immediately adjacent to a marked crosswalk. The RRFB is to be used at mid-block pedestrian crossings or pedestrian crossings at intersection approaches that are not controlled by another traffic control device (e.g. Yield signs, stop signs, hybrid pedestrian beacon or traffic signals). The RRFB may be applicable to a crosswalk across the approach to and/or egress from a roundabout.

The RRFB is normally dark, and initiates operation only upon pedestrian actuation. When activated, the RRFBs associated with a given crosswalk will commence operation of their alternating indications simultaneously and will cease operation simultaneously after a predetermined time period. A pedestrian instruction sign with the legend PUSH BUTTON TO TURN ON WARNING LIGHTS should be mounted adjacent to or integral with each pedestrian pushbutton.

## TRAFFIC CONTROL DEVICES IN RURAL AREAS

Most severe crashes at rural TWSC intersections are associated with *gap* recognition as opposed to *intersection* recognition. However, most public requests for improvements at TWSC intersections are for intersection recognition such as enhanced conspicuity (flashing LED stop signs, flashing beacons, etc). An engineering study of a TWSC intersection should investigate the causes of crashes or determine potential risk factors before a recommendation is made for new traffic control devices.

### Intersection warning sign

If there is an identified need to warn motorists on the major road of an upcoming intersection (and potential entering traffic), intersection warning signs (W2-1, W2-2, etc) should be considered. Typically these signs are used for rural locations where the major road speed limit is 40 mph or greater. Street name plaques may be considered with these signs. See MUTCD<sup>1</sup> section 2C.46 for more information.



### Stop Ahead sign (W3-1)

This sign may be added to warn drivers of an upcoming stop sign. Typically this sign is used in rural locations. See appendix III-09A in the NDDOT Design Manual for more information.

### Larger stop sign

The conventional stop sign size is 30"x 30". Replacing it with a larger stop sign (usually 36"x 36" or 48"x 48" in rural areas) can improve visibility.

### Left side stop sign

This countermeasure will give the driver two stop signs in their field of vision when approaching an intersection.

### Retro-reflective strip on stop sign supports

Installation of a red retroreflective strip on the sign support can improve driver recognition of the stop condition (see MUTCD<sup>1</sup> section 2A.21).

### Stop sign mounted flashing beacon

A flashing red beacon mounted to one or more of the stop signs on the minor road approach(s). Flashing beacons may be installed at a rural two-way stop controlled intersection at the option of the NDDOT if one of the below criteria are met:

- During a one-year period, there is evidence of drivers are still unaware of the stop sign even while these three devices were in place:
  - A stop ahead sign (W3-1)
  - Stop signs are 36" x 36" or larger on both the left and right side of the road
  - Stop sign supports with a red retroreflective strip (see MUTCD<sup>1</sup> section 2A.21)
- At an intersection where an overhead flashing beacon is removed and the AADT cross product is greater than 400,000



### Flashing LED stop sign

These signs are considered experimental and the effectiveness of them has not yet been proven. Until more conclusive research is available, NDDOT Programming Division expects to minimize the number of recommendations for these devices.



### Dynamic Speed Display Signs (DSDS)

Dynamic speed display signs are installed to provide a real-time dynamic display of a driver's vehicular speed at a particular location where speeding has been determined and documented to be a safety problem<sup>2</sup>.

### References:

1. FHWA, "[Manual on Uniform Traffic Control Devices](#)", 2009.
2. NDDOT, "[NDDOT Guidelines for the Use of Dynamic Speed Display Signs on the State Highway System](#)", November 2010.